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AUTHOR	Reigeluth, Charles M.
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ABSTRACT

The major purpose of instructional science is to prescribe optimal methods to bring about desired learning, and the purposes of this paper are twofold: (1) to encourage individuals in the discipline to think in terms of contributing to a collegial, or even competitive, building of a common knowledge base in instructional science, and (2) to briefly describe Component Display Theory, Elaboration Theory, and John Keller's work in motivation as three recent attempts to build such a base. In all three models, the instruction begins with a special kind of overview which is derived on the basis of a single kind of knowledge structure and epitomizes that knowledge structure rather than summarizing the course content. A 22-item reference list is provided. (RP)

INSTRUCTIONAL DESIGN,
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TOWARD A COMMON KNOWLEDGE BASE:

THE EVOLUTION OF INSTRUCTIONAL SCIENCE

By

Charles M. Reigeluth

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IDD&E Working Papers
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Charles M. Reigeluth, Editor
Sharon Heagerty, Production Editor
116 Hunnington Hall
Syracuse University
Syracuse, NY 13210

What Is (and Isn't) Instructional Science?

Instructional Science is a very young discipline that is concerned with understanding and improving the process of instruction. It's major purpose is to prescribe optimal methods to bring about desired learning. It is an applied science that represents a bridge beetween learning theory and instructional practice.

Instructional science is much like the applied science of medicine. That science is concerned with developing optimal methods for curing different types of diseases. In a similar way, instructional science is concerned with developing optimal methods for curing different types of ignorance. Medical science is different from biology, although much of it is derived from biology. Similarly, the science of instruction is different from the science of learning--it is concerned with what the teacher should do (or textbook, or computer-assisted instruction, or project, etc.) rather than with what the learner does. Naturally, however, many principles in the science of instruction have been derived from principles in the science of learning.

Finally, the science of medicine is different from the practice of medicine, although it plays an important role in good medical practice. Similarly, instructional science is different from instructional practice (or instructional development) in that it is concerned with what the instruction should be like rather than with how to make it that way (i.e., the practices and procedures for actually doing or making the instruction). Instructional scientists who are developing the discipline must draw both on educational practice (an inductive approach) and on a variety of related disciplines (a deductive approach), such as learning theory, cognitive theory, communication theory, and motivaton theory.

What Are Some Applications?

Instructional science is concerned with making textbooks better at teaching knowledge and skills of all kinds. It is concerned with helping teachers to give better class presentations, better oral responses to student questions, and better explanations to slow students who need individualized help. It is concerned with making educational films and TV programs better. All of these and many other concerns for the "betterment" of public education entail improving the effectiveness, efficiency, and motivational effects of instruction.

But the need for better methods of instruction does

not begin and end with public education. Adult (or continuing) education and distance learning (e.g., "correspondence" schools) need better methods of instruction to prevent attrition. Businesses and the military need better methods to reduce the amount of money and employee time needed for job training. The medical profession needs better methods of instruction for effective patient education and for professional training. Special education needs better methods of instruction to help teachers cope productively with physically and mentally handicapped children. And the list goes on and on. All indications are that, as our technological society increases its rate of change, education and training will become increasingly important, and there will be an increasing need to make our methods of instruction more effective, efficient, and motivational.

What Is Needed Now?

In sum, the discipline of Instructional Science is concerned with improving instruction in all kinds of settings in a direct and immediate way (unlike learning theory, which usually requires considerable creative interpretation and translation to be useful in prescribing methods of instruction). But instructional science is a very young and immature science. It has not yet been developed sufficiently to make the magnitude of contribution that is sorely needed. In fact, the discipline has been characterized by the generation of much piecemeal knowledge within decidedly antagonistic camps (especially behaviorist and cognitivist) ever since the pioneering work of Skinner and Bruner (whose intellectual heritage can be traced to Thorndike and Dewey, respectively). George Gropper (in press) has observed in a discussion of the discipline that "... there is no collegial, or even competitive, building of a common knowledge base with individuals making incremental contributions to it. Instead there are as many 'knowledge bases' as there are contributors. Such profusion, if other sciences serve as a guide, does not argue for the maturity or sophistication of the discipline."

There is indeed some truth in all theoretical perspectives. Each theory (or "knowledge base") provides a partial understanding of the real world of instruction in much the same way that each window in an unknown house provides a partial understanding of what the inside of the house is like. Some theories look at the same room through different windows (i.e., from different theoretical perspectives), while others look at completely different rooms (i.e., different types of objectives--e.g., teaching students how to discover natural laws vs. teaching them how to apply the second law of thermodynamics). One of our greatests needs at present is for instructional scientists

to recognize that there are different rooms in the house and that it is helpful, if not essential, that we look through more than one window of each room in order to get a complete picture of what each room is like. Only in this way can we proceed to build a common knowledge base. Hence, a top priority for all instructional scientists should be (1) to talk in terms of describing individual rooms instead of claiming to be describing the whole house, (2) to clearly identify which room is being described, and (3) to use all windows in a room so as to arrive at the best possible description of that room. Another of our greatest needs is (4) to attempt to integrate the destriptions of the individual rooms into a description of the whole house so that we will know how to use more than one "room" in the same piece of instruction.

Instructional science must be able to prescribe specific methods for optimizing different kinds of outcomes in the same piece of instruction, from such generic skills as being able to solve problems, being able to discover relationships, and being able to reason logically, to such content-specific skills as being able to recall a certain fact, being able to classify examples of a specific concept, and being able to follow a specific procedure. It will be helpful in describing each room if we recognize that all rooms have floors of some kind, walls of some kind, doors of some kind, lights of some kind, etc. Similarly, it will be helpful for prescribing specific methods for optimizing each kind of outcome if instructional scientist recognize that achieving each of those kinds of outcomes requires some method components that contribute to optimizing the effectiveness of the instruction, others that contribute to opimizing the efficiency of the instructon, and still others that contribute to optimizing the appeal of the instruction. It is also important to recognize that they all have some method components for organizing the instruction, (often called instructional strategies), others for delivering the instruction to the learner (e.g., media), and still others for managing the learner's interaction with the organizational and delivery aspects of the instruction (Reigeluth & Merrill, 1979).

The purposes of this paper are twofold: (1) to encourage individuals in the discipline to think in terms of contributing to a "collegial, or even competitive, building of a common knowledge base" by doing the four activities mentioned above, and (2) to briefly describe three recent attempts to do exactly that.

egra· ve Models of Instruction

Dur... the past six or seven years, substantial knowledge about learning, motivation, and instruction has been developed in the form of principles of instruction; and better instructional strategies have been developed for use in designing instruction. But, as was mentioned above, this knowledge has been either too piecemeal or too vague to be very useful to practitioners--teachers, textbook writers, instructional developers, and the like. During the past five years three important efforts have been undertaken to integrate a substantial amount of our existing knowledge (and to extend that knowledge where important gaps were found) into prescriptive models of instruction. The development of these instructional models (each of which is designed to optimize instruction on a different type of objective or goal) has drawn heavily on such diverse fields as cognitive science (especially information processing theory, artificial intelligence, schema theory, subsumption theory, and the structure of memory), behavioral learning theory, systems theory, communications theory, motivation theory, and educational practice.

There are at least two major types of design considerations: (1) micro considerations, which apply to teaching a single idea (such as the use of examples and practice); and (2) macro considerations, which apply to the teaching of many related ideas (such as sequencing and systematic review). About six years ago M. D. Merrill and his associates began to integrate much of the existing knowledge about micro design considerations (for single ideas) into six major models of instruction. Those models, along with prescriptions for their optimal use, are referred to as the Component Display Theory. About four years ago C. M. Reigeluth and M. D. Merrill and their associates began to integrate much of the existing knowledge about macro design considerations (for many related ideas) into three models of instruction. Those models, along with prescriptions for their use, are referred to as the Elaboration Theory of Instruction. These two sets of models are primarily concerned with strategies to optimize the effectiveness and efficiency of instruction (although the Elaboration Theory also devotes a moderate amount of attention to motivational considerations). Also, about two years ago J. M. Keller and his associates began to integrate much of the existing knowledge about considerations for the motivational design of instruction on both the micro and macro levels. These models are still in preliminary stages of development but show great promise for the discipline. These three sets of instructional models are briefly described below.

What Is the Component Display Theory?

Merrill's Component Display Theory (Merrill, in press; Merrill, Reigeluth, & Faust, 1979; Merrill, Richards,

Schmidt, & Wood, 1977) is a prescriptive theory that was developed to integrate existing knowledge about micro design considerations (i.e., considerations for teaching a single idea). It is comprised of (1) <u>six models</u> of instruction, each of which can be used in varying degrees of richness, and (2) a unique <u>system for prescribing</u> those models on the basis of the kind of objective for an idea. The degree of richness of each model is then prescribed on the basis of the difficulty of the objective in relation to the ability level of the students.

Each of the six models of instruction integrates knowlede about how to optimize instruction for one of six kinds of objectives for any given idea; and each kind of objective corresponds to a different level of cognitive processing for any given idea. The most fundamental difference is between objectives requiring <u>recall</u>, those requiring <u>application</u>, and those requiring <u>discovery</u>. Another difference is between recall objectives that require <u>verbatim</u> recall and those that require <u>paraphrased</u> recall. The third and final difference is between objectives that require recall of specific <u>instances</u> (or cases) and those that require recall of <u>generalities</u> (which apply to more than one case and make no reference to any specific case). To summarize, the six kinds of objectives are: (1) remember an instance verbatim, (2) remember an instance paraphrased, (3) remember a generality verbatim, (4) remember a generality paraphrased, (5) apply a generality to "new" instances, and (6) discover a "new" generality. Each of these six kinds of objectives requires different instructional strategies to optimize learning at that level of cognitive processing.

For the most common kind of objective--applying a generality to "new" instances--this theory calls for presenting three major strategy components: (1) a <u>generaltiy</u>, such as the statement of a principle or the definition of a concept, (2) <u>examples</u> of the application of that generality to specific instances, such as demonstrations of the principle or examples of the concept, and (3) <u>practice</u> in applying that generality to new instances, such as solving a new problem or classifying a new example of the concept. The practice should always be followed with <u>feedback</u> as to whether the student's answer was right or wrong and why. The examples and practice items should be <u>different</u> from each other in as many ways as the student is likely to encounter in the real world; and they should be arranged in a <u>progression of difficulty</u> from easy to difficult (which may include variation in response mode as well as manipulation of variable attributes). Also the generality, examples, practice, and feedback should all be clearly <u>separated and labeled</u>, as opposed to being in a continuous prose passage, in order to facilitate <u>learner control</u>.

Learner control (Merrill, 1979, in press) is the Component Display Theory's solution to the problem of individual differences among students and hence is its way of cost-effectively individualizing the instruction. It requires some brief student training in (1) the nature of each strategy component and (2) the way in which each component helps the student to learn (i.e., to overcome a different kind of learning problem). With such knowledge, the student is well equipped to pick and choose from the "menu" (primarily the generality, the examples, and the practice items) to make his or her optimal instructional design. For example, rather than designing "visual" instruction for some students and "verbal" instruction for others, you should make both representations available to all students, along with some knowledge about what to pick and choose when, rather than studying everything. (It is also likely that the vast majority of students are not strictly varbal or strictly visual and can therefore benefit from having both available if the objective is a difficult one.)

In order to increase the richness of this model, you could increase the number of examples and practice items. You could also enrich each of the three major strategy components (generality, examples, and practice) with such secondary strategy components as (1) an alternative representation (e.g., a diagram, picture, or flowchart), and/or (2) an attention-focusing device (e.g., underlining, exploded diagrams, or contrasts with common errors). The richest version of this model would include a very large number of examples and practice items, as well as both of the secondary strategy components described above (plus some that have not been mentioned here). But for an easy idea/objective in relation to student ability, the generality alone might be enough.

Space limitations do not allow us to describe the specific nature of, or specifications for, each of these strategy components, nor does it allow us to describe any of the other five models comprising the Component Display Theory. However, an inspection of the articles referenced above will reveal that just this one instructional model from the Component Display Theory incorporates work by Bruner (alternative representations, especially enactive, iconic, and symbolic), Glaser and Homme (ruleg--or rule-example--as generalities and examples), Skinner (shaping in the form of progression of difficulty, and overt responses in the form of practice), Rothkopf (mathemagenic informaon primarily under the rubric of attention-focusing devices and the nature of the practice items), Kulhavy (feedback for practice), Horn (information mapping for separating and labeling the strategy components), Gropper

(stimulus properties and response modes), Markle, Merrill, and Klausmeir (strategies for teaching concepts, especially instance divergence--examples and practice items as different as possible from each other--and "matched" or "close-in" nonexamples--instances which demonstrate common errors, specifically overgeneralization in the case of concept learning), to mention just a few of the most prominent people whose work is integrated into this one model.

An inspection of those articles will also reveal the influence of the prose learning people (especially Rothkopf and Frase), the taxonomy people (especially Gagne and Bloom), and the structure of memory people (especially Kintsch and Norman) in the derivation of the six kinds of objectives based on different levels of cognitive processing (including both storage and retrieval). Although the Component Display Theory integrates much existing knowledge, it is also important to point out that some of it was developed independently by Merrill and that a considerable amount of "new" knowledge was developed by Merrill as he encountered gaps in the existing knowledge needed to form such an integrative and complete set of models for different kinds of objectives. The classification of objectives according to both content type and performance level is one example of such original work.

It is very difficult to do justice in such short space to an instructional theory that synthesizes so much knowledge about learning and instruction. For more information, the reader is referred to Merrill (in press), Merrill, Reigeluth, and Faust (1979), and Merrill, Richards, Schmidt, and Wood (1977). The individual strategy components in each model have undergone considerable empirical testing in controlled settings. This body of research has shown significant differences for all of these strategy components (see Merrill, Olsen, & Coldeway, 1976, for a review). However, no research has been done to test each <u>whole model</u> to determine the relative importance and the interactive and duplicative effects of each of the strategy components comprising each of these six models.

<u>The Elaboration Theory of Instruction</u>

The Reigeluth-Merrill Elaboration Theory of Instruction (Reigeluth, 1979; Reigeluth, 1980; Reigeluth, Merrill, Wilson, & Spiller, in press; Reigeluth & Rodgers, 1980; Reigeluth & Stein, in press) is a prescriptive theory that was developed to integrate existing knowledge about <u>macro</u> design considerations (i.e., for many related ideas). It also considerably extends that knowledge where deficiencies were found. It is a major attempt to use both an analysis of the structure of knowledge and an

understanding of cognitive processes and learning theories to design strategies for selecting, sequencing, synthesizing, and summarizing the content for a course. It states that, if the instruction is designed according to the appropriate model, then that instructon will result in improved levels of achievement, synthesis, retention, transfer, and motivation.

Most instructional design experts have been using a hierarchical task analysis procedure based on Gagne's cumulative learning theory. But the hierarchical, learning prerequisite relationship is only one of four major kinds of relatonships in cognitive subject matter (one of four major kinds of knowledge structures). And the process of "cumulative learning" is only one of several major kinds of cognitive learning processes. Another major kind of cognitive learning process is represented by schema theory and its close cousin, subsumption theory. The formation of stable cognitive structures through successive differentiation has been almost totally ignored in current instructional practice, in spite of the monumental pioneering work of Ausubel.

The elaboration theory integrates both of these major kinds of cognitive learning processes (cumulative and subsumptive) and all four major kinds of knowledge structures into three models of instruction. It also has a system for prescribing those models on the basis of the goals for the whole course of instruction. Goals are classified as three types, and each type requires the formation of a different type of cognitive structure to optimize achievement of that type of goal. In all three models a subsumptive (or general-to-detailed) sequence is used to optimize the formation of stable cognitive structures. However, the way the subsumptive sesquence is operationalized varies considerably from one type of cognitive structure to another. These operationalizations represent a significant departure from Ausubel's instructional model (while still implementing his learning theory), especially in their attention to information processing theory and to Gagne's hierarchical theory of learning. Unlike the Component Display Theory's models, only one of these three models would be used for any given course.

In all three models, the instruction begins with a special kind of overview which (1) is derived on the basis of a single kind of knowledge structure and (2) epitomizes that knowledge structure rather than summarizing the course content. ("Epitomizing" means providing concrete instances and practice items as well as generalities for a few fundamental and highly representative ideas, whereas "summarizing" means providing only abstract generalities for all major topics.) Then the instruction proceeds to add

detail or complexity in "layers" across the entire breadth of the content of the course, one layer at a time, until the desired level of detail or complexity is reached. Learning prerequisites are introduced only as they become necessary _within each layer_.

Each model is adjusted in certain ways to make it appropriate for the ability level of the students and the complexity or difficulty of the content. For instance, the amount of material between review-and-synthesis components is adjusted to represent an "optimal learning load," which varies depending on the difficulty level of the content in relation to the ability level of the students. Considerable detail has been worked out on the nature of each model, and even on the procedures for designing instruction according to each model (see the above-referenced papers). But research on individual method variables comprising the models is practically nonexistant, and no research has been done to test each whole model to determine the relative importance and the interactive and duplicative effects of each strategy component comprising each model. Nonetheless, due to their firm foundation in learning theory, cognitive theory, and the structure of knowledge, and due to their intuitive appeal to educators, we are optimistic about their potential for significantly improving the effectiveness and appeal of instruction.

Motivational Design of Instruction

In addition to these two instructional theories, valuable work has been done recently on the motivational design of instruction (i.e., prescriptions for the improvement of the motivating characteristics of any given instruction). John Keller (1979) has done some very integrative and highly innovative work in developing a descriptive theory of motivation as it relates to instruction and performance. This work integrates knowledge about motivation from the full range of theoretical traditions, from pure behavioral to pure humanistic.

On the most general level, Keller's theory postulates that motivation is a function of person variables and environment variables. Therefore, it draws on _environmental theories_ comprised of conditioning principles and physiologically based drives (e.g., Hull, 1943; Skinner, 1953), _humanistic theories_ that postulate a fundamentally free will as the basis of motivation (e.g., Rodgers, 1951), and _social learning theories_ that look at the interactions between a person and the environment (e.g., Bandura, 1969; Rotter, 1966). Within the domain of social learning theory, Keller has drawn heavily on expectancy-value theory (e.g., Porter & Lawler, 1968), which assumes that motivation is a multiplicative function of expectancies and values. In

addition, Keller has drawn on aspects of attitude theory, decision theory, attribution theory, cognitive evaluation theory, equity theory, cognitive dissonance theory, locus of control, and learned helplessness (see Keller, 1979, pp 28-30, for references).

This integrative and innovative work on a descriptive theory of motivation as it relates to instruction has important implications for instructional scientist, but Keller is taking it one step further by developing prescriptions for the motivational design of instruction (Keller, in press). The prescriptions include method variables for arousing and sustaining attention, for connecting instruction to important needs, for building confidence in success, and for reinforcing behavior. Although much work remains to be done, Keller's efforts are another example of an attempt to build a common knowledge base in instructional science.

Conclusion

The three efforts summarized above are illustrative of the kind of integrative, multi-perspectived building of a common knowledge base that is so sorely needed at this point in the development of instructional science as a discipline. These are early, tentative, and as yet incomplete steps toward a common knowledge base, and there is a need to integrate these micro, macro, and motivational models into a unified theory--a set of unified models--of instruction, as well as to continue to modify and add to each of them. There is also a strong need for similar efforts to be made for other "rooms in the house" of instruction. If instructional science is to progress and mature as a discipline, it is essential that its contributors (1) specify the room of the house that they are working on, and (2) draw on all available knowledge--in all theoretical perspectives--in making their contributions to that room.

REFERENCES

Ausubel, D.P. The Psychology of Meaningful Verbal Learning. New York: Grune & Stratton, 1963.

Bandura, A. Principles of Behavior Modification. New York: Holt, Rinehart and Winston, 1969.

Gropper, G.L. A metatheory of instruction: A framework for analyzing and evaluating instructional theories and models. In C. M. Reigeluth (ed.) Instructional Design Theories and Models: An Overview of Their Current Status, in press.

Hull, C.L. Principles of Behavior. New York: Appleton-Century-Crofts, 1943.

Keller, J.M. Motivation and instructional design: A theoretical perspective. Journal of Instructional Development, 1979, 2, 26-34.

Keller, J.M. In C.M. Reigeluth (ed.) Instructional Design Theories and Models: An Overview of Their Current Status, in press.

Merrill, M.D. What is Learner Control? (Instructional Research Report, No. 137) San Diego: Courseware, Inc., 1979.

Merrill, M.D. The Component Dsiplay Theory. In C.M. Reigeluth (ed.), Instructional Design Theories and Models: An Overview of Their Current Status, in press.

Merrill, M.D., Olsen, J.B., and Coldeway, N.A. Research Support for the Instructional Strategy Diagnostic Profile (Tech.Report Series NO. 3.) Provo, Utah: Courseware, Inc. 1976.

Merrill, M.D., Reigeluth, C.M., and Faust, G.W. The instructional quality profile: A curriculum evaluation and design tool. In H.F. O'Neil, Jr. (ed). Procedures for Instructional Systems Development. New York: Academic Press, 1979.

Merrill, M.D., Richards, R.E., Schmidt, R.V. Wood N.D. The Instructional Strategy Diagnostic Profile Training Manual. San Diego: Courseware, Inc. 1977.

Porter, L. W. and Lawler, E.E. Managerial attitudes and performance. Hillmewood, ILL.: Richard D. Irwin, 1968.

Reigeluth, C.M. In search of a better way to organize instruction: The elaboration theory. Journal of Instructional Development, 1979, 2(3), 8-15.

Reigeluth, C.M. Meaningfulness and Instruction: Relating What is Being Learned to What a Student Knows. (IDD&E Working Papers, No. 1). Syracuse, NY: Instructional Design, Development & Evaulation Program, Syracuse University, 1980.

Reigeluth, C.M. and Merrill, M.D. Classes of instructional variables. Educational Technology. March 1979, 5-24.

Reigeluth, C.M., Merrill, M.D., Wilson, B.G. and Spiller, R.T., in press. The elaboration theory of instruction: A model for structuring instruction. Instructional Science, in press.

Reigeluth, C.M. and Rodgers, C.A. The elaboration theory of instruction: Prescriptions for task analysis and design. NSPI Journal, February 1980, 16-25.

Reigeluth C.M. and Stein F.S. The elaboration theory of instruction. In C.M. Reigeluth (ed.), Instructional Design Theories and Models: An Overview of their Current Status, in press.

Rogers, C.R. Client centered therapy. Boston: Houghton Miffin, 1951.

Rotter, J.B. Generalized expectancies for internal versus external control of reinforcement. Psychological Monographs. 1966, 80 (whole no. 609).

Skinner, B.F. Science and human behavior. New York: Macmillan, 1953.